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ORIGINAL RESEARCH

# SCORING PERFORMANCE VARIATIONS BETWEEN THE Y-BALANCE TEST, A MODIFIED Y-BALANCE TEST, AND THE MODIFIED STAR EXCURSION BALANCE TEST

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## ABSTRACT

***Background:*** The Modified Star Excursion Balance Test (MSEBT) and the Y-Balance Test- Lower Quarter (YBT-LQ) are utilized to assess dynamic postural stability. These assessments cannot be used interchangeably secondary to kinematic variations and performance differences. A Modified Y-Balance Test-Lower Quarter (MYBT-LQ) was developed to determine if a modification allows performance scores to be directly compared to the MSEBT.

***Purpose:*** The purpose of this research was to determine if reach distances were similar for young, healthy individuals between three different balance tests: the YBT-LQ, the MYBT-LQ, and the MSEBT.

***Study Design:*** Repeated measures, descriptive cohort study

***Methods:*** Twenty-eight participants (17 males, 11 females) were recruited from a convenience sample of young, healthy adults. Participants completed all testing within a single session and performed three trials in each direction, on each leg, for all balance tests. Scoring performance was calculated for each balance test using the average normalized reach distance in the anterior, posterolateral, and posteromedial directions. A one-way ANOVA was used to compare between-subject posteromedial and posterolateral scores, while anterior scores were analyzed using a Kruskal Wallis test. The intraclass correlation coefficient (ICC) was used to determine within-subject participant performance reliability.

***Results:*** Analyses indicated significant differences in the posterolateral and posteromedial reach directions between the YBT-LQ and MSEBT and between the MYBT-LQ and MSEBT, while no significant difference was found between the YBT-LQ and MYBT-LQ in any direction. No anterior reach differences were noted between any of the tests. Within-subject ICCs showed a very strong level of agreement between right and left anterior and right posteromedial reaches between all three tests, while only the YBT-LQ and MYBT-LQ demonstrated very strong agreement in all directions.

***Conclusion:*** Reach performance on the MSEBT differed from the performance on the YBT-LQ and MYBT-LQ in the anterior, posteromedial and posterolateral directions in this population. These findings further support the difference in motor control strategies used during these tests.

***Levels of Evidence:*** 2c

***Key Words:*** balance, postural stability, movement system

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## INTRODUCTION

The neuromuscular system plays an integral role in postural control during dynamic balance activities to limit the occurrence of loss of balance.[1] When there is a lack of coordination between the sensory and motor aspects of the neuromusculoskeletal system, balance is hindered, and postural instability may occur. Postural instability could lead to falls or uncoordinated and uncontrolled body movements that could ultimately produce injuries.[2] Previous research has shown that impairments within the neuromuscular system result in an increased risk for injury in young, active individuals, therefore warranting dynamic balance screening.[3] The Modified Star Excursion Balance Test (MSEBT) and the Y-Balance Test of the Lower Quarter (YBT-LQ) are reliable measures in the assessment of postural control within this population.[4] Gorman et al.[5] concluded that the YBT-LQ is a reliable derivation of the MSEBT, yet this could potentially lead clinicians to infer that these tests can be used interchangeably and that data collected during each test could be compared equally. Fullam et al.[6] identified kinematic variations and differences in performance scores on these tests, which has confirmed that they cannot be used interchangeably in the assessment of dynamic balance.[6] Specifically, authors of previous research have described significant differences have been identified in anterior reach distances comparing the SEBT and YBT-LQ.[6,7] The present study introduced and evaluated an alteration to the YBT-LQ that included a modification intended to counteract the physical alignment differences between the YBT-LQ and MSEBT.

The Star Excursion Balance Test (SEBT) utilizes an eight point star-shaped pattern, upon which an individual stands in the middle, balanced on one foot, while reaching as far as possible in each of the eight directions with the opposite leg.[8] The SEBT has been shown to be an effective assessment of dynamic postural control and is reliable at identifying risk for injury in individuals with chronic ankle instability, but limitations have also been discussed through extensive research.[9-11] Plisky and colleagues[8] determined that a difference in anterior reach distance of greater than four centimeters between each limb was associated with a higher risk of injury in high school basketball players. Robinson and Gribble[10] hypothesized that the eight reach directions within the SEBT were redundant in both healthy populations and in those with chronic ankle instability.[10] Reducing the number of reach directions tested, referred to as the Modified SEBT (MSEBT), has been a common suggestion for improving the administration and time efficiency of the SEBT, though the directions most appropriate to test for measurements continues to be debatable.[3,10,12,13] The directions that have been utilized for the MSEBT in other studies consist of anterior, posteromedial, and posterolateral directions.[6]

The YBT-LQ was developed based on the MSEBT protocol, but instead of reaching and touching a taped line, the individual stands on a stance plate and slides a reach indicator along a static frame while maintaining balance on the opposite lower extremity (Figure 1).[5] The YBT-LQ was developed to address some of the limitations of the SEBT to provide a more consistent dynamic balance assessment tool.[13] The YBT-LQ assesses dynamic limits of

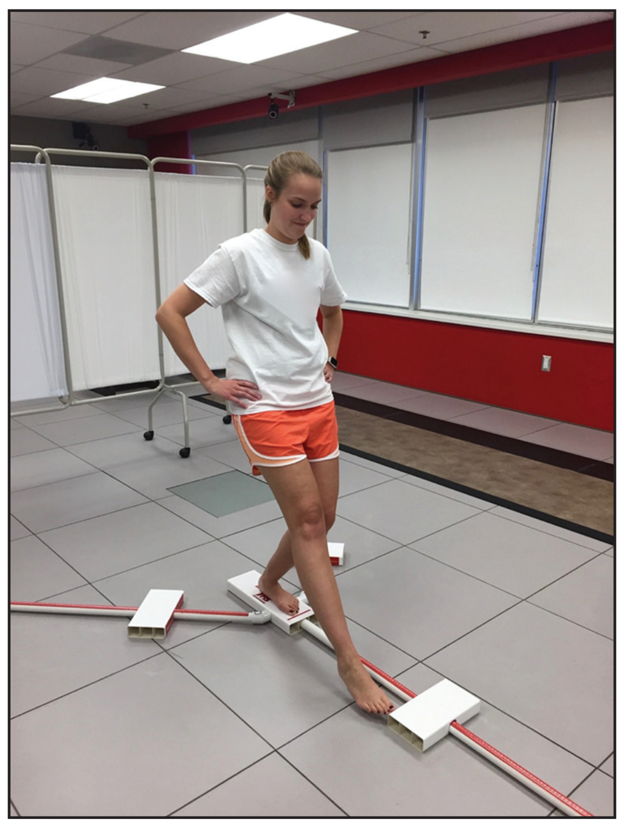

**Figure 1.** *Y-Balance Test anterior reach direction.*

stability during single limb stance while the opposite leg reaches in the same three directions as the MSEBT: anterior, posteromedial, and posterolateral.[3] It can also be utilized to assess risk of injury from functional asymmetries associated with young, athletic populations.[13,14] As with the SEBT, the YBT-LQ reach distances are normalized to leg length.[5] The YBT-LQ has also been proposed to provide a better assessment of movement quality as compared to the SEBT, by allowing more focused attention to observing the subject and their technique during performance of the test, rather than primarily on marking the reach distance.[13]

Because the YBT-LQ was developed from the MSEBT, it was hypothesized that the results would be equivalent or very similar between the two dynamic balance assessments.[7] However, Fullam et al.[6] and Coughlan et al.[7] have shown differences between the MSEBT and YBT-LQ in the composite anterior reach score as well as the sagittal plane hip and knee angular displacements, while no significant differences were noted in the posteromedial and posterolateral directions.[6,7] Differences in the anterior reach direction impacts the overall composite score of the evaluation, which affects the interpretation of test results.[6] It was suggested that these discrepancies resulted from variations in dynamic neuromuscular demands and/or the use of different postural control strategies during the task of reaching in each direction.[6,7] Differences among the reach directions between the YBT-LQ and the MSEBT are clinically relevant because patients with neuromuscular control deficits, such as those with chronic ankle instability, will likely perform differently on one test versus the other.[6]

During performance of the YBT-LQ, participants push a reach indicator slightly lateral to midline and inferior to the floor level of the stance foot, which varies from the midline and floor-level reach performed during the MSEBT. A modification to the reach indicator of the YBT-LQ was introduced by the current researchers in order to better match an individual's physical position and alignment during performance of the MSEBT and the YBT-LQ (Figure 2). This modification allowed the reach indicator to be pushed from a central location, at stance foot level, similar to the physical parameters of the MSEBT. This modification of the YBT-LQ, the Modified YBT-LQ (MYBT-LQ), was intended to counteract the physical differences between testing parameters so that any additional discrepancies in performance could be attributed to other factors. As the MSEBT and YBT-LQ cannot be used interchangeably at this time, secondary to performance differences and kinematic variations, further research assessing the kinematics and postural strategies required to perform these tests have been deemed necessary.[6] The purpose of this research was to determine if reach distances were similar for young, healthy individuals between three different balance tests: the YBT-LQ, the MYBT-LQ, and the MSEBT.

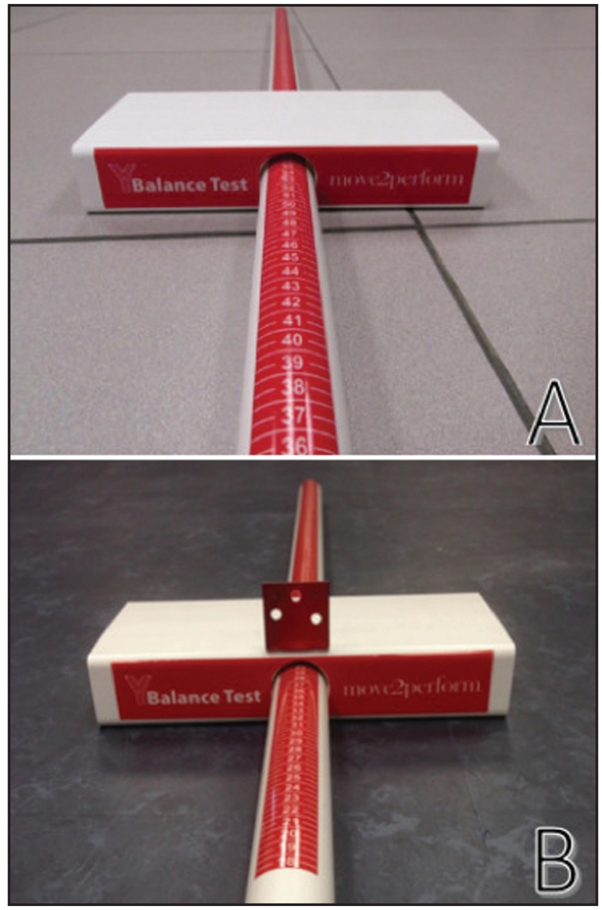


**Figure 2.** *Y-Balance Test reach indicator (A) and Modified Y-Balance Test reach indicator (B).*

## METHODS

Prior to recruitment of participants, approval was obtained from the university's Institutional Review Board (IRB). A convenience sample of twenty-eight participants (11 females, 17 males, mean age = 25.0 ± 2.2 years) was recruited from a pool of healthy, young individuals located in Roanoke, VA. Inclusion criteria for the study required participants to be healthy adults aged 18-35 years who self-reported that they were free of any lower extremity injuries in the prior six months and did not have any diagnosed neurological or balance disorders. Participants were excluded from the study if any of the following were present: lower extremity amputation, history of lower extremity fracture, vestibular disorders, undergoing current treatment for inner ear/sinus/upper respiratory infection, concussion within the prior three months, past medical history of surgery for a lower extremity injury within the prior six months, currently pregnant, or medically prohibited from participating in physical activities. Prior to engaging in any formal data collection, participants read a description of the study and signed a consent form.

Participants completed a total of three different balance tests during a single testing session, including the YBT-LQ (Functional Movement Systems™, Danville, VA), the MSEBT, and the MYBT-LQ. Performances were normalized using leg length, and maximal reach distances for anterior, posterolateral, and posteromedial directions. Prior to testing, each participant received an orientation to the balance assessments, and bilateral lower extremity leg lengths were measured. Leg length data were collected by the same researcher for all participants for consistency of measurements. The order of the three balance tests was randomized to account for the impact of fatigue and learning effect. Each test was demonstrated and scored by the same researcher who was certified to administer the Y-Balance Test through Functional Movement Systems™ (Danville, VA). Prior researchers have demonstrated good to excellent intra-rater reliability (0.85-0.91),[13] and good[3] to excellent[13] interrater reliability (0.80-0.85 and 0.99-1.0, respectively) when the YBT-LQ was performed by trained examiners. Participants were allotted three practice trials per lower extremity and direction prior to testing. A two-minute rest period was required after completion of all practice trials prior to initiation of testing.

Participants performed all versions of the tests barefoot in order to decrease external stability of the ankle provided by shoes. During YBT-LQ testing, the foot was placed on the center of the stance plate while the other remained free for reaching. Per the Y-Balance Test protocol, participants were instructed to stand on the center of the stance plate with toes behind the pre-set line and to push the reach indicator in the red target area toward the direction being tested. The reach distance was measured at the trailing edge of the reach indicator to the nearest 0.5 cm. Additionally, per Y-Balance Test protocol, trials were discarded and repeated if the participant failed to maintain unilateral stance on the stance plate (i.e. reach foot touched the floor), failed to maintain reach foot contact with the reach indicator on the target area while in motion (i.e. kicked the reach indicator), used the reach indicator for stance support, failed to keep the entire plantar aspect of the stance foot in contact with the stance plate (i.e. lifting the heel), or failed to return the reach foot to the starting position in a controlled manner (i.e. loss of balance).

In contrast to the YBT-LQ, during the MYBT-LQ participants pushed the reach indicator by using an additional fabricated tab that was centered on the superior surface of the reach indicator and flush with the trailing edge (Figure 2). The fabricated tab was attached to the top of the Y Balance reach indicator such that the reach foot was centered over the reach indicator and was not effectively reaching below the stance surface or lateral to midline, which is physically more similar to the MSEBT.

To perform the MSEBT, the participants stood on the YBT stance plate and followed the same protocol as the YBT-LQ, with the exception of sliding the reach indicator. Instead of pushing the reach indicator, participants reached out and lightly touched the YBT frame with the reach foot in each of the three testing directions (Figure 3). Performance of the MSEBT on the YBT frame was deemed necessary to minimize the effect of perceptual differences associated with standing on a raised surface versus the floor. The distances were recorded in the same manner as for the YBT-LQ (within 0.5 cm). The trial was invalid if the participant did not maintain unilateral stance limb support throughout the trial (loss of balance), transferred body weight onto the reach foot, failed to keep the entire plantar surface of the stance foot

**Figure 3.** *Modified Star Excursion Balance Test as performed atop the Y-Balance Test frame.*

in contact with the stance plate, and/or if the reach foot did not contact the YBT frame.

### Statistical Methods

Prior to conducting this study, an a priori power analysis was conducted to determine the necessary sample size using G*Power 3.1 (© 2010-2019 Heinrich Heine Universität Düsseldorf). Calculations based on a similar study conducted by Fullam and colleagues[6] indicated that a sample size of 27 was necessary to achieve 80% power. A between- and within-subjects analysis was performed comparing the differences between the normalized reach distances on the YBT-LQ, MSEBT, and MYBT-LQ. Posterolateral and posteromedial reach distances for the YBT-LQ, MYBT-LQ, and MSEBT were analyzed utilizing a one-way ANOVA and Tukey's HSD post hoc tests, while anterior reach distances were analyzed using a Kruskal Wallis test due to non-normality. Intraclass correlation coefficients (ICCs), using a consistency definition and a two-way mixed model, were analyzed to determine the reliability of individual participant performance among the three tests. All participants served as their own controls. Statistical analysis was completed using IBM SPSS Statistics for Windows, Version 24.0. (Armonk, NY: IBM Corp) with an alpha value of 0.05 utilized to determine any statistically significant different results were found among the variables.

## RESULTS

The normalized reach distances of the YBT-LQ, MYBT-LQ, and MSEBT were analyzed for the 28 participants. A significant main effect was found between subjects for the average reach distances for the posterolateral [right: $F_{(2)}=4.816$, $p=0.011$, left: $F_{(2)}=5.455$, $p=0.006$] and posteromedial [right: $F_{(2)}=3.425$ , $p=0.037$, left: $F_{(2)}=3.121$, $p=0.049$] reach directions between the three tests. The average anterior reach distances were not found to be significantly different [right: $X^2_{(2)}=0.779$, $p=0.677$, left: $X^2_{(2)}=1.869$, $p=0.393$] between any of the three tests (Figure 4). Tukey's HSD post-hoc analyses indicated significant differences in the right posteromedial reach direction between the MYBT-LQ and MSEBT (Figure 5 and Table 1), and significant differences in bilateral posterolateral reach directions between the YBT-LQ and MSEBT and between the MYBT-LQ and MSEBT (Figure 6 and Table 1). There was no significant difference between the YBT-LQ and MYBT-LQ in any reach direction ($p=0.23$), no significant difference between any of the three tests in the left posteromedial reach direction ($p=0.51$),

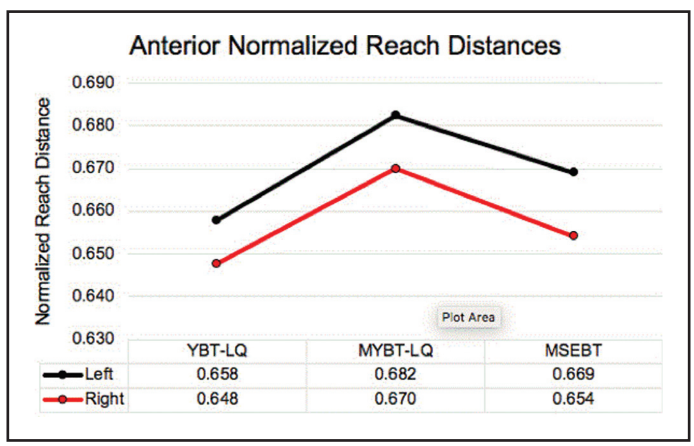


**Figure 4.** *Normalized scores for all anterior reach directions. YBT-LQ = Y-Balance Test Lower Quarter; MYBT-LQ = Modified Y-Balance Test Lower Quarter; MSEBT = Modified Star Excursion Balance Test.*

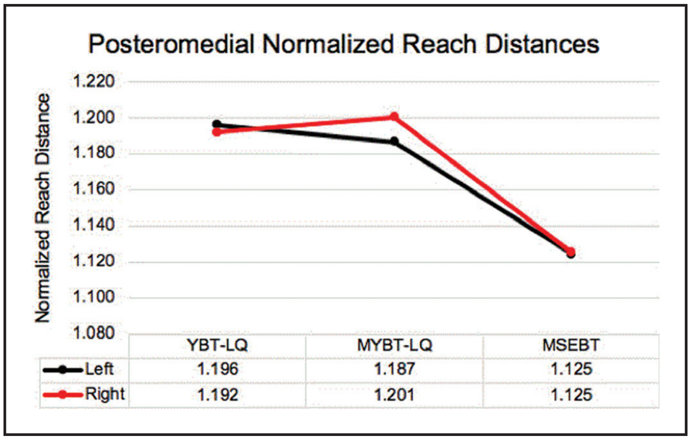


**Figure 5.** *Normalized scores for all posteromedial reach directions. YBT-LQ = Y-Balance Test Lower Quarter; MYBT-LQ = Modified Y-Balance Test Lower Quarter; MSEBT = Modified Star Excursion Balance Test.*

**Table 1.** *Tukey's HSD Post Hoc Results.*

| Reach Direction | Comparison | *p*- value |
|---|---|---|
| Left Posteromedial | YBT-LQ vs MYBT-LQ | 0.949 |
| | YBT-LQ vs MSEBT | 0.061 |
| | MYBT-LQ vs MSEBT | 0.120 |
| Right Posteromedial | YBT-LQ vs MYBT-LQ | 0.962 |
| | YBT-LQ vs MSEBT | 0.091 |
| | MYBT-LQ vs MSEBT | 0.050 |
| Left Posterolateral | YBT-LQ vs MYBT-LQ | 0.992 |
| | YBT-LQ vs MSEBT | 0.018 |
| | MYBT-LQ vs MSEBT | 0.014 |
| Right Posterolateral | YBT-LQ vs MYBT-LQ | 0.995 |
| | YBT-LQ vs MSEBT | 0.021 |
| | MYBT-LQ vs MSEBT | 0.027 |

YBT-LQ= Y-Balance Test Lower Quarter; MYBT-LQ= Modified Y-Balance Test Lower Quarter; MSEBT= Modified Star Excursion Balance Test

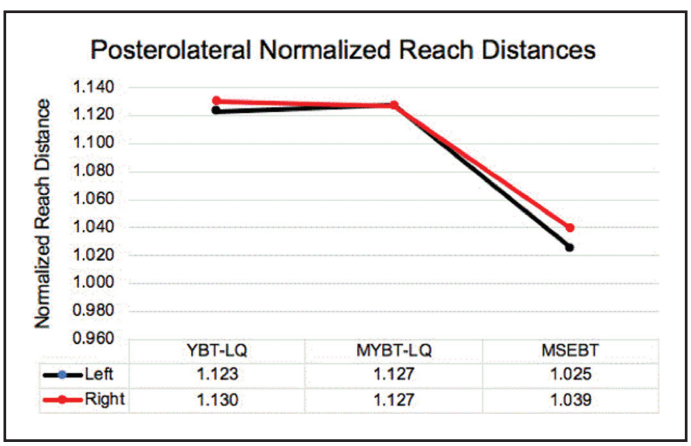


**Figure 6.** *Normalized scores for all posterolateral reach directions. YBT-LQ = Y-Balance Test Lower Quarter; MYBT-LQ = Modified Y-Balance Test Lower Quarter; MSEBT = Modified Star Excursion Balance Test.*

and no significant difference between the YBT-LQ and MSEBT in the right posteromedial reach direction (p = 0.14) (Table 1).

Intraclass correlation coefficients comparing YBT-LQ and MYBT-LQ demonstrated very strong agreement for all reach directions, and all three tests demonstrated very strong agreement in the anterior reach direction (Table 2). Reaches in the right posteromedial direction showed very strong agreement for MYBT-LQ and MSEBT and for YBT-LQ and MSEBT, while there was less strong agreement among the remaining tests and reach directions (Table 2).

## DISCUSSION

The primary aim of the present study was to determine if there were differences between reach distances during performance of the YBT-LQ, the newly developed MYBT-LQ, and the MSEBT. Analyses revealed that participants performed more similarly on the YBT-LQ and MYBT-LQ, and less similarly on the MSEBT, indicating that the modification to the YBT-LQ did not significantly alter performance outcomes of the YBT-LQ. It has previously been proposed that differences occurred between performance in the YBT-LQ and SEBT due to variations in the position of the reach foot; the SEBT is performed by reaching directly in line and at floor level, while the YBT-LQ is performed by reaching slightly lateral to the position of the stance foot and at a level slightly below that of the stance foot.[7] The MYBT-LQ was specifically developed for the present study to evaluate these differences inferred by Coughlan and colleagues[7]. The YBT-LQ and MYBT-LQ showed very strong agreement in overall reach distance performance, which suggests that differences shown in previous research between the YBT-LQ and MSEBT should not be attributed to the foot position relative to the reach indicator or stance foot.

Variations in performance between the MSEBT and YBT-LQ have also been attributed to varying feedback and feedforward mechanisms of postural control.[7] In the YBT-LQ, it is proposed that a continuous feedback loop is present due to the proprioceptive input to the reach foot as it pushes the reach indicator during testing. This feedback loop is thought to assist participants in determining how far they have reached and when they are nearing the limits

**Table 2.** *Intraclass Correlation Coefficients by Lower Extremity and Reach Direction.*

| Reach Direction | Tests | Right | Left |
|---|---|---|---|
| Anterior | YBT-LQ and MYBT-LQ | 0.825 | 0.909 |
| | YBT-LQ and MSEBT | 0.909 | 0.935 |
| | MSEBT and MYBT-LQ | 0.893 | 0.941 |
| Posteromedial | YBT-LQ and MYBT-LQ | 0.958 | 0.929 |
| | YBT-LQ and MSEBT | 0.847 | 0.572 |
| | MSEBT and MYBT-LQ | 0.874 | 0.558 |
| Posterolateral | YBT-LQ and MYBT-LQ | 0.886 | 0.902 |
| | YBT-LQ and MSEBT | 0.723 | 0.735 |
| | MSEBT and MYBT-LQ | 0.758 | 0.778 |

YBT-LQ= Y-Balance Test Lower Quarter; MYBT-LQ= Modified Y-Balance Test Lower Quarter; MSEBT= Modified Star Excursion Balance Test

of their stability. In contrast, the MSEBT utilizes a feedforward mechanism of postural control as participants reach to their limits of stability prior to making contact with the support surface; this means that participants must rely heavily on anticipatory actions before they receive sensory input from the ground.[7] The present study appears to further support a difference in postural control mechanisms between these tests. The MYBT-LQ altered the physical alignment to more closely approximate the MSEBT, yet the reach distance outcomes remained similar to those of the YBT-LQ. Reaching out while utilizing proprioceptive feedback from the reach indicator may have provided an advantage during the YBT-LQ and MYBT-LQ that allowed for greater reach distances in the posteromedial and posterolateral directions. In the present study, participants displayed more difficulty locating the YBT frame while performing the MSEBT atop it, compared to the YBT-LQ and MYBT-LQ. This could be due to the role of the proprioceptive systems and a continuous feedback loop that is present during the YBT-LQ and MYBT-LQ.

Contrary to the findings of Coughlin and colleagues,[7] no statistically significant differences were noted between the three tests in the anterior direction. In order to perform these balance assessments, participants utilize three different sensory systems (visual, vestibular, and proprioceptive) to maintain postural control.[7] It is likely that participants performed similarly on the three tests in the anterior direction due to the increased visual input and awareness of their body position during completion of the anterior reach. In the posteromedial and posterolateral directions, the participants could not see the labeled frame, were unaware of their reach distances during the performance of each trial, and had to seek the rail positions during the MSEBT. Participants likely relied more heavily on vestibular and proprioceptive input to perform the posteromedial and posterolateral reaches which may have led to more variation between the overall group's performances in these directions.[7] In contrast, participants' performance of the anterior direction likely utilized all three sensory systems, yielding a more uniform reach distance in this direction. Additionally, unlike participants in the Coughlan[7] study, the participants in the present study were not members of organized collegiate sports teams at the time of testing. This may have resulted in a group of participants who did not have the proprioceptive abilities typically demonstrated by collegiate athletes. These participants, however, may be more representative of average healthy active young adults, making the findings applicable to a larger subset of the population.

## Clinical Relevance

The outcomes of this study support prior findings indicating that performance scores on the YBT-LQ and MSEBT are not equivalent and thus, the assessments should not be used interchangeably. A modification designed to align the physical parameters of the two tests (MYBT-LQ) did not result in significant differences in reach distances when compared to the MSEBT, and therefore is not suggested for future use of the YBT-LQ. Choosing between the MSEBT and the YBT-LQ should continue to be at the discretion of the sports or rehabilitation professional and should best match the needs of the professional and their athlete/patient, since both tests are reliable and have demonstrated injury prediction capabilities. Given that the primary difference between the two tests is the pattern associated with the reach, sports and rehabilitation professionals should select the test that best aligns with the individual's sports, recreation, or job duties. Those who are able to utilize environmental inputs during their movements may benefit from testing using the YBT, while those who are required to target in open space should choose the MSEBT.

A potential limitation in the present study is the method of testing during the MSEBT. Standing atop the YBT frame allowed for consistent positioning and measurement of reach distances, but it did not address the altered visual perception that may result from standing on a raised surface.

## CONCLUSION

Results of the present study show strong correlations between performance on the YBT-LQ and the MYBT-LQ, suggesting that feedback from the reach indicator may be responsible for variations noted when comparing performance to the MSEBT. These findings also indicate that there is no need to modify the YBT-LQ reach indicator to more closely replicate the physical parameters of the MSEBT, as the reach distance outcomes do not differ significantly. Results of this study also indicate that healthy active young adults demonstrate performance variations in the posterolateral and posteromedial reach directions when performing the YBT-LQ, MYBT-LQ, and MSEBT, while anterior reach directions do not differ. Future research that investigates the effect of standing on a raised versus level surface during completion of the MSEBT (i.e., on the YBT frame) would be beneficial in helping determine the cause of variable findings on these balance tests.

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